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DUST POLLUTION OF ATMOSPHERIC AIR IN TASHKENT CITY

Annotation

Urban particulate matter (PM) pollution has become one of the major environmental challenges associated with rapid urbanization and increasing anthropogenic activities. This study aimed to investigate the spatial and temporal distribution of particulate matter concentrations in the atmospheric air of Tashkent during the summer seasons from 2013 to 2023. PM concentration data collected from 12 air quality monitoring stations operated by the Hydrometeorological Service Agency under the Ministry of Ecology, Environmental Protection and Climate Change of the Republic of Uzbekistan were analyzed. Geographic Information System (GIS) techniques and the Inverse Distance Weighting (IDW) interpolation method were applied to generate thematic maps illustrating the spatial distribution of particulate matter concentrations.

Keywords: particulate matter (PM), air pollution, Geographic Information System (GIS), Inverse Distance Weighting (IDW), spatial analysis, urban air quality, Tashkent, urbanization.

ПЫЛЕВОЕ ЗАГРЯЗНЕНИЕ АТМОСФЕРНОГО ВОЗДУХА ГОРОДА ТАШКЕНТА

Аннотация

Загрязнение атмосферного воздуха городов взвешенными твердыми частицами (PM) является одной из наиболее актуальных экологических проблем, обусловленных ускоренной урбанизацией и ростом антропогенной деятельности. Целью данного исследования является анализ пространственно-временного распределения концентраций взвешенных твердых частиц в атмосферном воздухе города Ташкента в летний период 2013-2023 гг. В исследовании использованы данные о концентрации PM, полученные на 12 станциях мониторинга качества атмосферного воздуха Агентства гидрометеорологической службы при Министерстве экологии, охраны окружающей среды и изменения климата Республики Узбекистан. Для анализа пространственного распределения концентраций PM были применены технологии географических информационных систем (GIS) и метод интерполяции Inverse Distance Weighting (IDW).

Ключевые слова: взвешенные твердые частицы (PM), загрязнение атмосферного воздуха, географические информационные системы (GIS), метод обратного взвешенного расстояния (IDW), пространственный анализ, качество атмосферного воздуха, Ташкент, урбанизация.

TOSHKENT SHAHRI ATMOSFERA HAVOSINING CHANG BILAN IFLOSLANISHI

Annotatsiya

Shahar atmosfera havosining chang bilan ifloslanishi urbanizatsiya jarayonlarining jadallashuvi va antropogen faoliyatning kuchayishi bilan bog‘liq eng dolzarb ekologik muammolardan biri hisoblanadi. Mazkur tadqiqotning maqsadi 2013-2023-yillar davomida yoz faslida Toshkent shahri atmosfera havosidagi chang konsentratsiyasining fazoviy va vaqt bo‘yicha taqsimlanishini tahlil qilishdan iborat. Tadqiqotda O‘zbekiston Respublikasi Ekologiya, atrof-muhitni muhofaza qilish va iqlim o‘zgarishi vazirligi huzuridagi Gidrometeorologiya xizmati agentligining atmosfera havosi sifatini kuzatish bo‘yicha 12 ta monitoring stansiyasidan olingan chang konsentratsiyasi ma’lumotlaridan foydalanildi. Chang konsentratsiyasining hududiy taqsimlanishini baholash uchun geografik axborot tizimlari (GIS) texnologiyalari hamda Inverse Distance Weighting (IDW) interpolatsiya usuli qo‘llanildi.

Kalit so‘zlar: chang, atmosfera havosining ifloslanishi, geografik axborot tizimi (GIS), IDW, fazoviy tahlil, atmosfera havosi sifati, Toshkent shahri, urbanizatsiya.

Introduction. Urban air pollution is currently recognized as one of the most pressing global environmental challenges. In recent years, the rapid pace of urbanization, the continuous increase in the number of motor vehicles, the expansion of industrial production, and the growing demand for energy resources have led to a significant rise in the emissions of atmospheric pollutants. In particular, carbon dioxide (CO_2), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxides (NO_x), tropospheric ozone (O_3), particulate matter (PM), and dust are among the major air pollutants that contribute to the deterioration of urban air quality and pose significant risks to human health and urban ecosystems [1, 2, 4].

Urban air pollution caused by particulate matter originating from both natural and anthropogenic sources is currently recognized as one of the most significant environmental and public health challenges. Particulate matter is among the major atmospheric pollutants, and its concentration is influenced by natural processes, such as wind erosion, dust transport from deserts and arid regions, and the resuspension of soil particles, as well as anthropogenic activities, including road traffic, construction works, industrial emissions, energy production, and the abrasion of road surfaces. In densely populated urban areas, the combined effects of natural and anthropogenic dust sources contribute substantially to the deterioration of air quality. In arid and semi-arid regions, including Tashkent, dust pollution is influenced not only by local anthropogenic emissions but also by regional natural sources. High traffic density, intensive construction activities, and industrial operations generate considerable amounts of dust, which combine with mineral particles transported by wind from surrounding desert areas, resulting in elevated concentrations of airborne particulate matter. Therefore, identifying the natural and anthropogenic sources of urban dust, assessing their relative contributions, and investigating their spatial and temporal distribution patterns are of considerable scientific and practical importance for improving urban air quality, protecting public health, and ensuring environmental sustainability.

Literature review. In recent years, extensive research has been conducted on urban air pollution caused by particulate matter ($PM_{2.5}$ and PM_{10}), with particular emphasis on assessing its concentration, understanding its formation mechanisms, investigating its spatiotemporal variability, and identifying both natural and anthropogenic sources. Modern studies increasingly integrate remote sensing data, machine learning techniques, chemical transport models, isotope analyses, and Geographic Information System (GIS) technologies to improve the assessment and management of urban air quality.

Wu et al. investigated the annual cycle of $PM_{2.5}$ across East Asia using machine learning algorithms and demonstrated that the spatial and seasonal variations in particulate matter concentrations are strongly influenced by meteorological conditions and anthropogenic emissions [13]. Zhao et al. demonstrated that aerosol-cloud interactions play a significant role in enhancing $PM_{2.5}$ pollution in China [14]. Song et al. assessed the sources of carbonaceous materials in $PM_{2.5}$ aerosols in Guangzhou, South China, using radiocarbon (^{14}C) isotope analysis [11]. Liu, Jin, and Duan developed a novel hybrid modeling approach for multi-step forecasting of $PM_{2.5}$ concentrations and evaluated its performance in four major Chinese cities. [9]. Liang et al. comprehensively reviewed recent advances in $PM_{2.5}$ observations, source identification, and pollution control strategies [8]. Tao et al. examined the chemical composition of $PM_{2.5}$, aerosol optical properties, and their relationships across China. Their findings showed that sulfate, nitrate, ammonium, and organic aerosols constitute the major fraction of $PM_{2.5}$ mass, while variations in chemical composition significantly influence aerosol optical characteristics and atmospheric visibility [12]. Long et al. developed a grid-independent version of the GEOS-Chem chemical transport model for integration into Earth system models, significantly improving the simulation of the formation, transformation, and long-range transport of atmospheric pollutants [10]. Overall, the reviewed studies indicate that urban particulate matter pollution is a complex environmental process driven by the combined effects of natural and anthropogenic factors. Accurate assessment of the spatiotemporal variability of $PM_{2.5}$ and PM_{10} requires the integrated application of remote sensing, GIS technologies, machine learning algorithms, chemical transport models, and geochemical analytical techniques. Although considerable progress has been achieved worldwide, comprehensive investigations into the combined impacts of regional dust transport, local anthropogenic emissions, and rapid urbanization on particulate matter pollution remain limited in Central Asia, particularly in Tashkent.

Research methodology. This study analyzed the spatial and temporal variations in dust concentrations during the summer season in Tashkent, Uzbekistan, over the period 2013-2023. The research methodology consisted of several sequential stages, including data collection and preprocessing, spatial analysis using Geographic Information System (GIS) techniques, thematic mapping based on the Inverse Distance Weighting (IDW) interpolation method, and statistical analysis of the obtained results.

To assess the level of atmospheric air pollution in Tashkent, dust concentration data measured during the summer months (June, July, and August) between 2013 and 2023 were obtained from the database of the Hydrometeorological Service Agency under the Ministry of Ecology, Environmental Protection and Climate Change of the Republic of Uzbekistan. The dataset was collected from 12 atmospheric air quality monitoring stations distributed across different parts of the city.

Geographic Information Systems (GIS) provide an efficient platform for the acquisition, integration, analysis, and visualization of spatial data [3,5,6]. The spatial distribution of dust concentrations across Tashkent was modeled using the Inverse Distance Weighting (IDW) interpolation method. IDW is one of the most widely used deterministic interpolation techniques in environmental studies, enabling the estimation of values at unsampled locations based on observations from nearby monitoring points [7]. As a result, a series of thematic maps illustrating the spatial distribution of dust concentrations in Tashkent for the period 2013-2023 were produced and analyzed using five-year temporal intervals.

Results and discussion. Figure 1 illustrates the spatial distribution of particulate matter (PM) concentrations in the atmospheric air of Tashkent during the summer seasons of 2013, 2018, and 2023. Analysis of the thematic maps indicates that the spatial distribution of particulate matter underwent considerable changes throughout the study period, characterized by a substantial decline in pollution levels between 2013 and 2018, followed by a subsequent increase by 2023.

In 2013, the majority of the city’s territory was characterized by PM concentrations ranging from 121 to 140 μg/m³, indicating a relatively high level of dust pollution across Tashkent. The highest concentrations (141-160 μg/m³) were observed in the central and central-eastern parts of the city, particularly in the vicinity of monitoring stations No. 2, 14, 15, and 18, where localized pollution hotspots were identified. These elevated concentrations are likely associated with intensive traffic flows, the presence of industrial facilities, and extensive construction activities, all of which represent major anthropogenic sources of particulate emissions. A marked improvement in the spatial distribution of particulate matter was observed in 2018. Dust concentrations across nearly the entire urban area declined to 61–80 μg/m³, and high-pollution zones largely disappeared. By 2023, however, particulate matter concentrations exhibited an increasing trend once again. Most parts of the city recorded PM concentrations within the range of 81-100 μg/m³, although the extremely high concentrations observed in 2013 were no longer present. At the same time, relatively lower dust concentrations (61-80 μg/ m³) were identified in the north-central part of the city, particularly around monitoring stations No. 12, 16, and 19. This localized reduction may be associated with the presence of relatively larger green spaces in these areas or with local wind circulation patterns that facilitate the dispersion of airborne particulate matter.

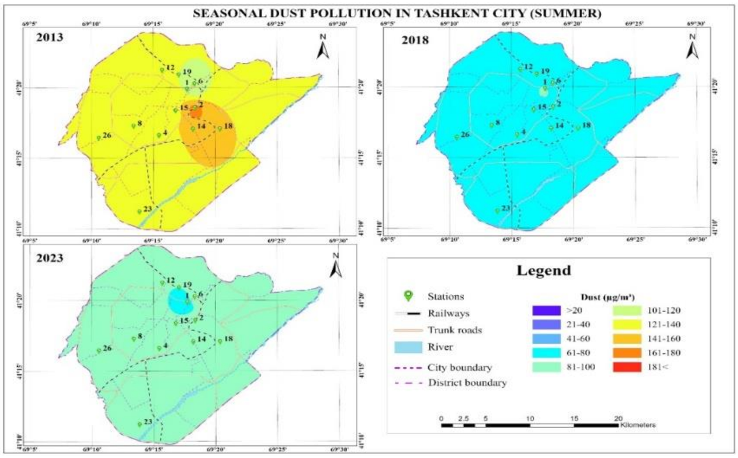

Fig.1. Seasonal variation in dust emissions into the air in Tashkent city during summer between 2013 and 2023

A comparison of the three observation periods reveals a distinct temporal pattern in particulate matter pollution across Tashkent. Dust concentrations decreased substantially between 2013 and 2018 but increased again during the period from 2018 to 2023. This recent increase is likely related to the accelerated pace of urbanization in Tashkent, including the expansion of residential and infrastructure construction, the rapid growth in vehicle numbers, and the reduction of urban green spaces. In addition, natural factors characteristic of the summer season, such as prolonged dry weather, limited precipitation, soil surface desiccation, and regional dust transport events, may have further contributed to elevated atmospheric dust concentrations.

Conclusion. The results of this study revealed significant spatial and temporal variations in summer dust pollution in the atmospheric air of Tashkent during the period 2013-2023. The thematic maps generated using the Inverse Distance Weighting (IDW) interpolation method demonstrated that dust concentrations were relatively high across most parts of the city in 2013, with localized pollution hotspots occurring particularly in the central and central-eastern districts. In contrast, a substantial reduction in dust concentrations and a more homogeneous spatial distribution were observed in 2018, indicating an improvement in urban air quality. However, dust concentrations increased again in 2023, suggesting the re-emergence of an unfavorable trend in the city’s environmental conditions.

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